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Permafrost Distribution Research Progress on Qinghai-Tibet Plateau

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Abstract

Climatic effects receive much concern about permafrost accelerated degradation of the Tibetan Plateau under the background of the global climate warming, so it is more significant monitoring change process of permafrost state. Firstly, reviewed distribution methods of the permafrost, including annual average temperature method and elevation model method; subsequently summarized permafrost distribution change prediction model, including physical model, empirical model, half physical model and half empirical model; finally, summarized problems and deficiencies remaining in this research and discussed the research emphases.

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Keywords-Qinghai-Tibet Plateau; permafrost; distribution prediction

It is more significant monitoring change process of permafrost state in the evolution of a petroliferbus basin[1], which is closely related to environmental factors and engineering stability.

1. Distribution Methods of the Permafrost on Qinghai-Tibet Plateau

1.1. Annual average temperature method

Z.T.Nan[2]simulated permafrost distribution of the Tibetan Plateau, using annual average ground temperature data measured ground temperature and numerical simulation, and annual average 0.5° is the watershed.G.D.Cheng[3] proposed annual average ground temperature lower -0.5° as one of the good

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parameter to relatively stable zone of permafrost from the angle of engineering geology. Based on the former investigations, and considering system deviation of analysis data and actual situation of permafrost distribution of the Tibetan Plateau from WDC, annual average ground temperature -1° is the watershed to distinguish permafrost zone, and applying the criteria in the case of global warming, which is called the average annual temperature method[4].

1.2. Elevation model method

G.D.Cheng[5] analyzed zonality law of permafrost in high altitude zone by fitting permafrost lower bound in northern , and obtained Gaussian distribution function about the geographical latitude and the lower bound of permafrost, the formula is as(1), which is called elevation model , H is the height of the permafrost lower bound (m), Φ is the geographic latitude (°).G.Xin and G.D.Cheng[6] obtained the formula(2)to determine the distribution of permafrost with elevation model , P =1(0) is a (no) distribution of permafrost; h is the elevation of each grid cell (m).

$$H = 3650 exp\,[-0.003(\varphi-25.37)2] + 1428 \tag{1}$$

$$P = \begin{cases} 1, h > H \\ 0, h \le H \end{cases} \tag{2}$$

Both from distribution range or from area of the permafrost, simulation permafrost using annual average temperature is closer toobservation data of WDC [4].

As a main parameter of the energy balance on the earth surface, land surface temperature (LST) is one of the boundary conditions to numerical permafrost models and is also an important content of permafrost observations. Traditionally we obtain LST through meteorological stations. However, because such station represents only a single point situation, the traditional approach usually may not reflect average condition well in a larger area, especially when LST is variable to land covers. With the development of remotely sensed technology, land surface temperature observation based on the remote sensing data becomes an important method. However, due to the complicated terrain surface, the data acquisition, processing, and analysis might not be accurate enough. Further analysis prior to use is necessary [7].

2. Permafrost Distribution Prediction Model

At present, prediction models about domestic and international environment changes in the permafrost can be divided into three categories [8]: First, analysis of physical processes establishes the physical process model usually based on the theory of heat conduction, which has been widely used in the study interaction between permafrost and the engineering because of its clear physical meaning. Second, experimental analysis establishes statistical or empirical models to predict permafrost based on field observation data [6]. Third, semi-physical and semi-empirical model to predict changes in the permafrost combined with physical processes and experience [9, 10]. With rapid development and wide application of new technologies such as remote sensing and GIS, permafrost prediction model has been combined with "3S" technologies.

2.1. Physical model

Physical model describes exchange process between heat and water of permafrost and atmospheric system on the basis of the surface energy balance [7], its biggest advantage is dynamic and no empirical coefficients and model portability [11]. But, it is very difficult to obtain accurate physical parameters and the soil layer information in the actual distribution simulation and change prediction of permafrost, especially for large-scale study, so given the appropriate assumptions and idealized conditions for the practical study problems, it is difficult to calculate based on actual data, so it is difficult to promote wide range, and the physical model can only be at some point with observed in detail or small area data. In recent years, foreign physical model have been established, Lunardini [12] established Lunardini model according to the theoretical formula of the ablation depth and ablation time. Smith and Rise borough [13] established the function model between permafrost and climate. Hoelzle [14] established surface energy flux and distribution model on the base of gas energy balance.

Permafrost data is relative lack on the Qinghai-Tibet Plateau, so domestic scholars seldom used physical model to simulate and predict changes in permafrost distribution [15]. So far, only Li SX[16] established the permafrost temperature field model by the differential equation of permafrost temperature on the Qinghai-Tibet Plateau permafrost studies , but it is not suitable for distributed simulation of large area, and lack of access to many of the parameters affecting the accuracy of the results.

2.2. Empirical model

Empirical model directly links permafrost to limited variables to establish a empirical formula for the suitable calculation, which can only predict the existence of permafrost, and is lack in the permafrost dynamics change.

Nelson proposed a freezing index model [17] based on Stefan model[18], freezing index model can be accurately divided into non-frozen permafrost zone and three frozen soil types in the high-latitude permafrost, which is widely used the response research under climate change in high latitude permafrost. Li.X [6] applied to Nelson's freezing index model on Qinghai-Tibet Plateau, to Simulate the entire permafrost distribution , due mainly used in high latitudes, simulation results are not satisfactory. These models are large and medium-scale distribution model, which is mainly affected by latitude, longitude and altitude [7].

In a small area, permafrost distribution is mainly affected by factors of local geography and geology. Haeberh [19] established a purely empirical model to describe the relationship between frozen soil and climate, latitude, altitude in the 1970s. Keller [20] developed the purely empirical model into a computer model- PERMAKART, and as a research area in Switzerland, which entered the DTM data to determine the distribution of permafrost in ArcGIS , and adjusting the parameters to apply to permafrost studies in different regions.

Permafrost table temperature model(TTOP) rapidly has been applied to permafrost analysis in recent years to establish the relationship between table temperature and the temperature by removing the impact of vegetation and snow cover [21].B.Q.Wu used TTOP to analyze applicability of test about 21 observation sites in permafrost along the Qinghai-Tibet Highway, the results show that the application of the model works was well, but which is only limited to the observation sites, and not to the entire plateau region.

2.3. Remote sensing technology

In recent years, remote sensing technology has been applied to the permafrost model, terrain parameters from DEM and information from satellite remote sensing image can be effectively combined to simulate the distribution of permafrost [7]. Heggem used DEM and land remote sensing images to conduct land type, which estimates the average annual ground temperature of different types of spatial distribution, simulated permafrost distribution in southern Mongolia [22]. Etzelmuller [23] combined with DTM and remote sensing data to analyze the relationship between topography, land cover and permafrost distribution. Gruber [24] used elevation data to calculate solar radiation income, and through calibration work of the vegetation cover map and no snow cover reflectivity map to simulated permafrost distribution. Leverington [25] applied artificial neural network to determine whether there is permafrost In Canada YukonMayo area.

Chen.S.B [26, 27, 28] inversed emissivity by MODIS data to conduct permafrost distribution in Qiangtang based on the difference to the emissivity of the surface material, which provides a new way of thinking in Qinghai-Tibet Plateau about permafrost from remote sensing perspective .K.Wang [28] used surface temperature inversion and comprehensive analysis of multi-variable model to simulate permafrost distribution along the Qinghai-Tibet Highway based on RS / GIS.

3. Conclusion

(1)A lot of high-precision observational data has great help in model of comparison and simulation, but the permafrost data is lack and not continuous on entire Qinghai-Tibet Plateau, if there are more and more uniform distribution data from the measured site, using regression method [7] to get the ground temperature of the Tibetan Plateau will be closer to the real situation. It is necessary to conduct continuous large-scale spatial analysis and observation test in future research.

(2)Quantitative retrieval theory has been applied to study of the distribution of permafrost, but it is not mature in theory and methods, and need to further strengthen research. It is a question worth exploring to establish model for discrete points in the extent to remote sensing pixel scale [28].

(3)It is an important data for high resolution remote sensing images to monitor the pattern of permafrost and periglacial processes, but so far, this work is still relatively small study [29]. Therefore, it is an important future direction using high-resolution remote sensing data to monitor permafrost. And a variety of models are seldom applied in the Tibetan Plateau, it is necessary to apply permafrost distribution model to the Tibetan Plateau.

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